NERRS Science Collaborative Progress Report for the Period 9/01/13 through 2/28/14

Project Title: Exploring the cost-effectiveness of restored marshes as filters of runoff pollution in a world of rising seas.

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Project start date: 10/01/12

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A. Progress overview:

For this reporting period we had 3 goals: 1) synthesize the results from the Conservation and Restoration Awareness Survey, 2) synthesize the results from the nutrient dosing experiments, and 3) have a MAT meeting to present the survey and nutrient experiment results as well as obtain feedback from the MAT for the next round of experiments. We met all 3 of the aforementioned goals and will also report some preliminary results from measurements taken during this reporting period such as marsh sediment accretion and plant diversity. Lastly, we will present the results from the weir methods experiment where we mimicked 3 different sea level rise (SLR) scenarios prior to the nutrient dosing experiments.

A.1. Conservation and Restoration Awareness Survey

The first project goal for this reporting period was to synthesize the results from the Conservation and Restoration Awareness Survey. This research aims to bridge the communication gap and explore any misunderstandings among stakeholders and scientists working to reduce polluted water run-off into the Gulf Coast. Since the final product for this project is a decision-support tool, which will include cost comparisons and multiple scenarios to help stakeholders decide how to invest resources in managing Alabama's coast, we want to be sure to use a "common language" that resonates with stakeholders and decision-makers. The first step in building the model requires having a baseline assessment of the stakeholders' understanding and knowledge about the key components of the restoration project, including the language used to describe the science. What communication challenges and opportunities are imbedded discussing water conservation and marshland restoration efforts in southwest Alabama? What terminology resonates with stakeholders and should be used when creating the decision support tool as well as educational, informational and promotional materials?

A.1.1. Research Questions and Methodology

Our research goal is to assess the communication challenges and opportunities in the Weeks Bay Reserve Project. We proposed two research questions related to stakeholder communication:

> RQ 1: What do the Weeks Bay Reserve's stakeholders and decision-makers already know about conservation and restoration efforts?
>
> RQ 2: What terminology is most familiar to the stakeholders and has the potential to improve public understanding of conservation and restoration efforts in this case?

To answer these questions we created and distributed an online survey (https://www.surveymonkey.com/s/LCP3DD2). The survey questions are an attempt to quantify respondents' awareness and attitudes about conservation and ecosystems. The survey was modeled after a similar public opinion poll about ecosystem services conducted by The Nature Conservancy (Metz & Weigel 2013). Our audience consisted of, but was not limited to, members of the Weeks Bay Foundation, volunteers and MAT team members. We reached this audience by posting the survey on the Weeks Bay Facebook page, made available on iPads at the Week Bay's reserve and via an email invitation to participate. One week after the survey launched, a reminder e-mail was sent. A total of 201 surveys were completed between July 10, 2013 and August 20, 2013.

A.1.2. Survey Respondents

The survey respondents ranged in age from 18-27; 65% were female and a majority considered his or her self of white ethnicity. Thirty-two percent held master degrees while 19% have a 4-year college degree. The survey respondents have a high interest (58% are extremely interested; 27% very interested) and concern (60% are extremely concerned; 29% very concerned) for the environment. Thirty-seven percent said they visited a natural area outdoors more than once a week and 63% of our respondents seek information about the environment at least once a week.

A.1.3. Results

A.1.3.1. Research Question 1: Stakeholders' Awareness & Attitudes about Conservation & Ecosystem Services

Thirty-five percent of our respondents felt he or she knew enough information about the following terms to be able to tell others: ecosystem services, ecosystem functions, nutrient pollution, eutrophication, and stormwater pollution. This group, 35% of the most of engaged stakeholders, understand the language of the project and scientific terminology more broadly. The remaining 65% were less knowledgeable, however most (80%) agreed that the indirect benefits nature provides and restoring marshlands is very or extremely important.

Stakeholders are interested in exploring options for reducing the amount of polluted water run-off into the Gulf Coast. Forty-eight percent agreed research of ecological functionality was a critical concern to them followed by research on ecosystem services, research on different types of plant survival and last, research on cost-effectiveness.

Additionally, we asked respondents to rank how trustworthy various information sources are: conservation organizations had the highest ranking with 51% followed by scientists (46%), professors at local universities (47%), and famers (44%). In open-ended responses, many respondents clarified that scientists are trustworthy because they are less likely to have ulterior motives and may be most concerned about using science to improve the health of the ecosystem.

A.1.3.2. Research Question 2: Stakeholders' Knowledge of Marshland Restoration & Run-off

As part of the survey, a "Pop Quiz" was created to assess the stakeholders' prior knowledge about ecosystem services definitions and concepts. Questions generally pertained to the health of the environment's water and the impact human and natural interactions can have on the water. In most cases more than 80% of the stakeholders can differentiate all the different concepts that the decision model would include: ecosystem functions and ecosystem services, nutrient pollution, stormwater pollution, and excessive algal growth. Additionally, 86% of respondents agree that planting native grasses, marshes, along areas where water is most likely to become polluted can alleviate stormwater run-off in the Gulf.

There are several opportunities for building a decision support tool that blends scientific and stakeholder terminology. In fact, the audience is very knowledgeable and already perceives scientists as trustworthy. The Nature Conservancy findings had focused on how scientists can address the importance of conservation through open communication, simple; yet easily understandable vocabulary use and stressing the mutually beneficial relationship between nature and people, the same guidelines could be used here.

Overly used terms and concepts can gradually lose the impact necessary to effect stakeholders' environmental decisions. Which tends to make stakeholders believe the issues are not as important, does not affect them or such an overwhelming problem that they have minute chance of solving. It is possible that words like *environment*, *ecosystem* and *ecosystem services* won't resonate with 65% of the stakeholder audience, and we should consider using terms like *land, air, water, natural areas* and *nature's benefits* instead.

It is a strategic challenge to be precise and yet simplify the language used to discuss ecosystem restoration with Weeks Bay Reserve stakeholders. However, in any project, considering language choices is the first step in building a more trustworthy relationship between scientists and stakeholders. Stakeholders cannot trust what they do not fully understand, but if scientists can effectively communicate the significance of the project and related decision-making scenarios, stakeholders will be ready to engage.

A.1.4. References:

Metz, D. & Weigel, L. (2013). The language of conservation 2013: The updated recommendations on how to use communicate effectively to build support for conservation. *Public Opinion* Research, 1-13. Abstracted retrieved from Fairbank, Maslin, Maullin, Metz & Associates and Public Opinion Strategies.

A.2. Nutrient experiment

A.2.1. Methodology

Goal 2 for this reporting period was to synthesize the results from the nutrient dosing experiments. The experiments occurred over summer-fall 2013 and included testing of nutrient filtration across 3 different groundwater flow rates (low, mid, and high) in all 5 restoration designs (0%, 25%, 50%, 75%, and 100% planting densities) in both ambient and sea level rise (SLR) conditions at 2030. The low flow scenario was set to mimic retention pond scenarios (18 L^{-1} $plot^{-1}$ day^{-1}) and was pumped for 21 consecutive days. The mid flow was set to mimic the drainage from light rain events (36 L^{-1} $plot^{-1}$ day^{-1}) and was pumped for 12 consecutive days. The high flow scenario mimicked a short and intense rain event (398 L^{-1} $plot^{-1}$ day^{-1}) and was pumped for 1 day. The simulated pollution plume was pumped through a diffuser plate at the upland section of each plot, which dispersed the flow evenly throughout the plot, with subsequent sampling on the final day of pollution plume pumping at a porewater collection well located at the downland portion of each plot. All of these flow scenarios were subjected a simulated pollution input containing target concentrations of 200 μM NO_3^- and 5 mM Br^-. NO_3^-

will be actively used by biological processes (plant uptake, denitrification, etc.) whereas Br^- is not biologically active and is considered our conservative tracer. The only process that will change the concentration of Br^- is dilution, the use of this conservative tracer paired with a non-conservative tracer (NO_3^-) allows for accurate calculations, through dilution correcting, of the quantity of the input pollution (NO_3^-) that is removed as it travels through the marsh. Porewater samples were analyzed for concentrations of NO_3^- + NO_2^-, dissolved inorganic nitrogen (DIN), and Br^-. Porewater NO_3^- + NO_2^- and DIN concentrations will allow for suggestions of overall nitrogen processing (input + ambient N) across treatments both with and without SLR. Samples were also taken directly from the input and prior to the experiments to get exact nutrient loading estimates in the introduced solution and samples prior to the experiment were used to estimate ambient porewater nutrient concentrations. Analysis of Br^- allows for calculations of how much the introduced solution was diluted with ambient porewater (i.e. not from the introduced solution) prior to arriving at the downland porewater sampling well. The ambient porewater that dilutes the introduced solution contains NO_3^- as well, therefore this ambient NO_3^- must accounted for accurate dilution corrected NO_3^- + NO_2^- concentrations. The following equation was used to accurately calculate the NO_3^- + NO_2^- concentration in the introduced solution:

Dilution corrected $[NO_3^- + NO_2^-]$ = (*Downland well – Natural x Dilution) ÷ (1-Dilution)* (eq. 1).

Downland well corresponds to the measured NO_3^- + NO_2^- concentration at the downland well, *Natural* is the ambient (i.e. background) NO_3^- + NO_2^- concentration, and *Dilution* the proportion of the introduced solution that is diluted prior to reaching the downland well (i.e. change in Br^- concentration from the input to the downland well).

All of these measured variables (NO_3^- + NO_2^-, DIN and Dilution corrected NO_3^- + NO_2^-) were statistically analyzed using a 2 way ANOVA (Planting density x weir presence) to determine if planting density or SLR conditions had an effect on the measured variables in each of the flow scenarios. After this test, a 1 way ANOVA was run (Planting density) at each site with individual SLR scenarios (ambient and 2030). These 1 way ANOVAs were used to analyze the effect of planting density at an equivalent SLR. Significance for all tests was considered at $p < 0.05$.

A.2.2. Results

Results indicate that SLR had no effect on porewater nutrient concentrations (NO_3^- + NO_2^- and DIN across all flow scenarios (Figures 1,2). However, we did find a significant decrease in DIN concentrations with planting density for the ambient SLR condition (No Weir; Figure 2). These results suggest that higher planting densities decrease porewater nutrient concentrations more effectively (i.e. remove more porewater nutrients) than the lower planting densities at this site. We found no effect of SLR or planting density for the removal of NO_3^- + NO_2^- from the introduced solution in the low and high flow scenarios. However, in the mid flow scenario, we find higher values in the ambient SLR condition (No weir) than the 2030 SLR condition (Figure 3). These results are strongly influenced by the large $NO_3^- + NO_2^-$ concentrations for the lower planting densities (0 and 25%) and suggest higher N uptake from our introduced solution in the more vegetated treatments, since there were lower dilution corrected $NO_3^- + NO_2^-$ concentrations in the more vegetated treatments, however when analyzing these results more closely with a 1 way ANOVA, we find no statistical significance.

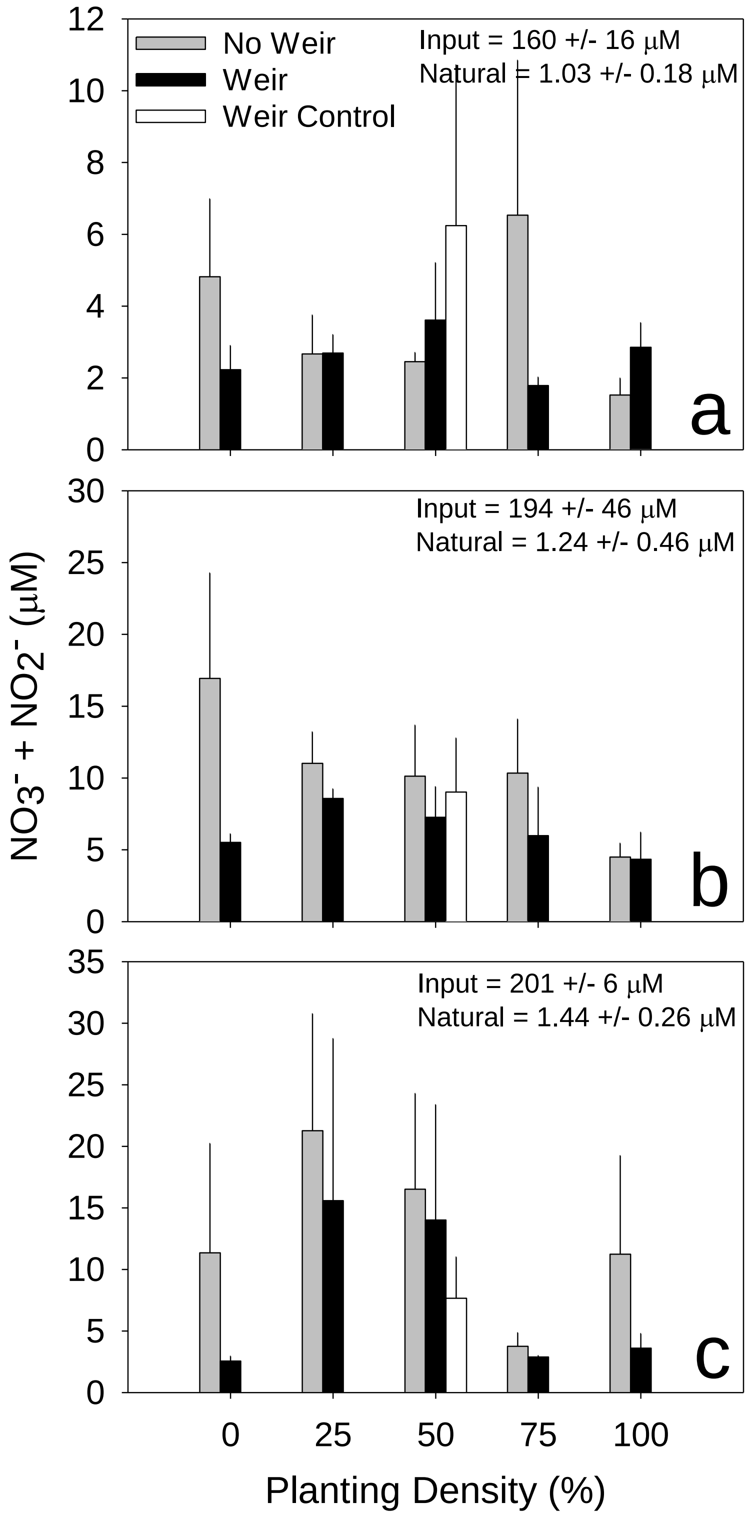

Figure 1. Porewater NO_3^- + NO_2^- concentrations across all planting densities. The top panel (a) represents the low flow scenario, middle panel (b) is the mid flow scenario, and the bottom panel (c) is the high flow scenario. Error bars indicate ± 1 S.E.

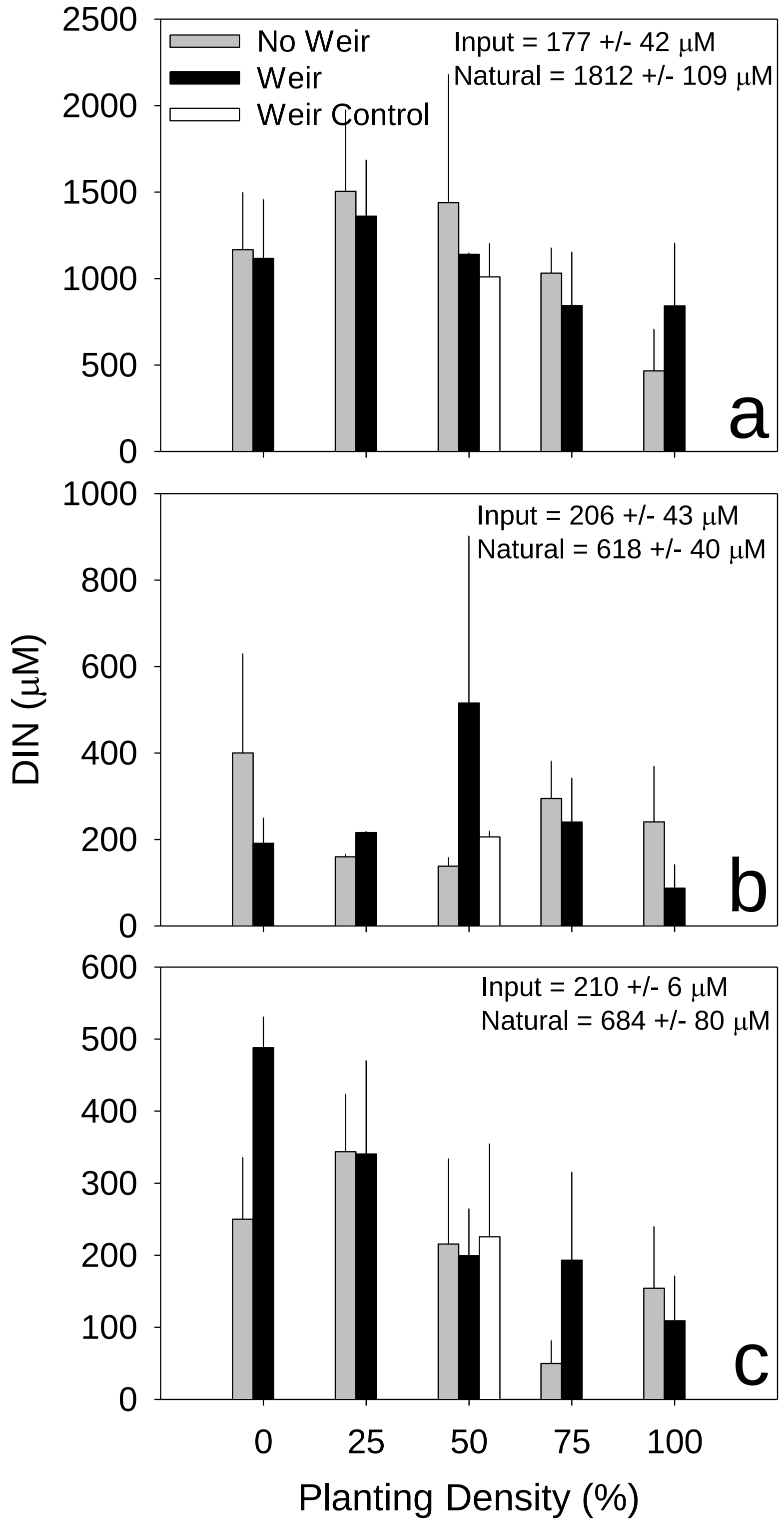

Figure 2. Porewater DIN concentrations across all planting densities. The top panel (a) represents the low flow scenario, middle panel (b) is the mid flow scenario, and the bottom panel (c) is the high flow scenario. Error bars indicate ± 1 S.E.

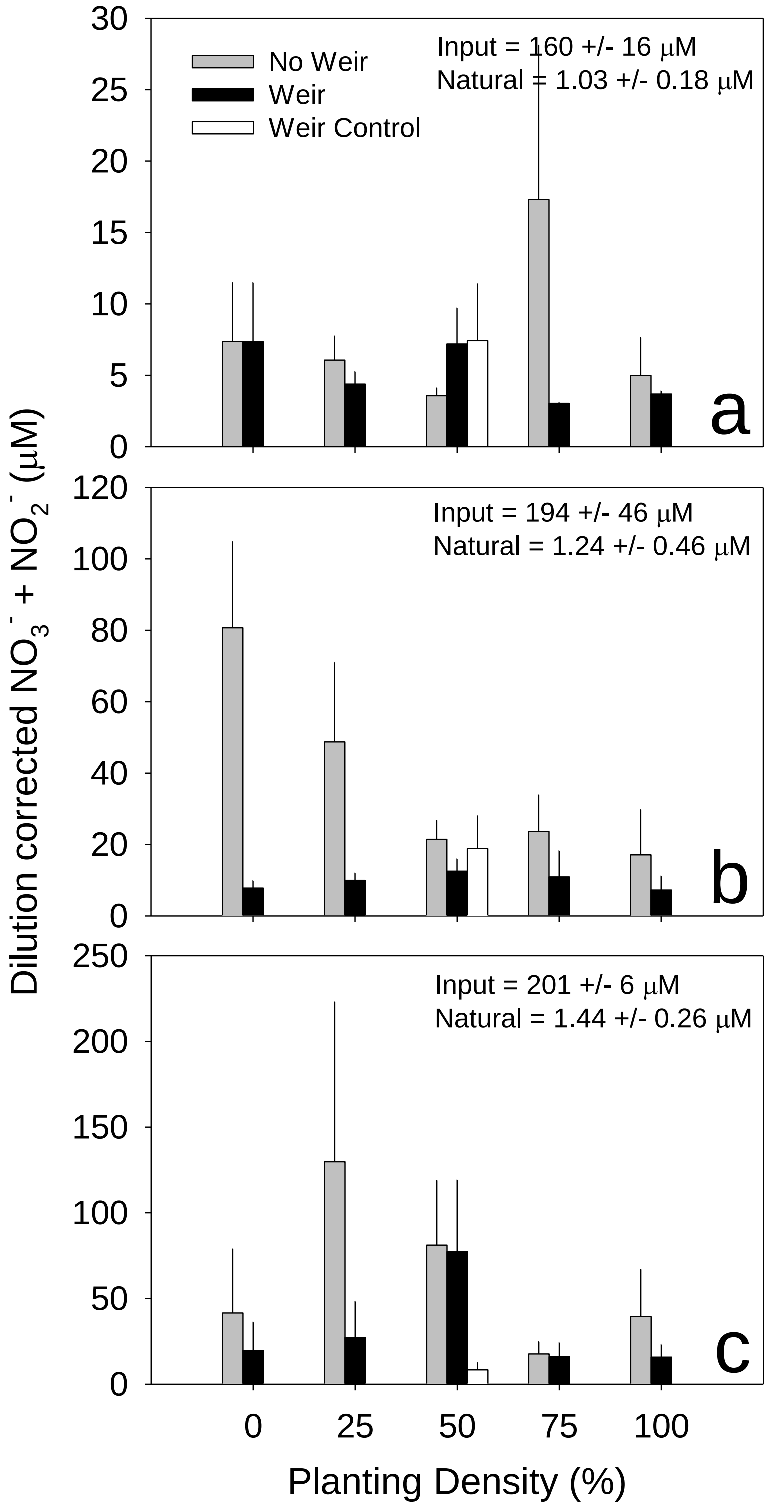

Figure 3. Dilution of pollution plume corrected porewater NO_3^-+ NO_2^- concentrations across all planting densities. The top panel (a) represents the low flow scenario, middle panel (b) is the mid flow scenario, and the bottom panel (c) is the high flow scenario. Error bars indicate ± 1 S.E.

A.2.3. Summary

The overall summary of this nutrient experiment is that SLR and planting density had little to no effect on nutrient processing so far. The background concentrations of DIN are high in these restored sites; thereby the plots have ample supply of nutrients. This high supply of nitrogen leaves little possible uptake from the introduced solution since the plants are already saturated with nutrients. These results are not surprising in that the marsh has only been planted for a relatively short period of time (less than 1 year) and likely has not had time to fully develop the microbial communities responsible for many nitrogen removal processes. Some of our previous research at the Grand Bay NERR suggests that at approximately 2 years after planting, a restored marsh was removing large quantities of porewater nutrients; thereby reducing nutrient pollution in coastal water bodies. Our predictions are that the next round of nutrient experiments will show larger differences among planting densities for nutrient removal capacity but the extent of the effects of SLR on these nutrient removal processes is unknown, since we are the first to test this in situ for restored black needlerush marshes.

A.3. MAT meeting

The final goal for this reporting period was to meet with the MAT to present our research findings as well as obtain their input for implementation into the next round of experiments. On December 6th, 2013, we had a MAT meeting where we presented the survey and nutrient experiment results. We then discussed the next round of nutrient experiments, which the MAT had suggestions for a one modification to the experimental protocol. The MAT suggested we run the low flow scenario in Site 2 as well as Site 3 for comparative purposes since the ambient DIN concentrations in Site 3 are extremely high. We are going to do this low flow comparison for both sites 2 and 3 at the next nutrient experiment.

A.4. Sediment accretion and plant diversity

A.4.1. Sediment accretion

During August of 2013, sediment accretion markers were placed at the upland (relative high elevation) and lowland (relative low elevation) portions of each plot. The marker was placed directly on the sediment surface and was composed of a thin layer of feldspar, which is white in color. In December 2013, sediment cores were taken at these sediment accretion plots with the amount of sediment above the white feldspar marker measured.

During this initial 3.5 month period, surface accretion tended to be higher at lower elevations than at higher elevations within experimental plots, regardless of SLR treatment (Figure 4). It is currently unclear to what extent SLR will influence the magnitude of these responses over time. Furthermore, surface accretion tended to be higher within control (ambient sea level) plots at the lower planting densities, a trend that tended to be reversed at higher planting densities (Figure 5).

These results are preliminary and will be updated with more measures of accretion. Sediment accretion is important to measure in both ambient and SLR conditions since marshes rely on the accumulation of sediment to maintain their elevation. Given future SLR conditions, marshes will have to accumulate more sediment than in the past to maintain their elevation and survival.

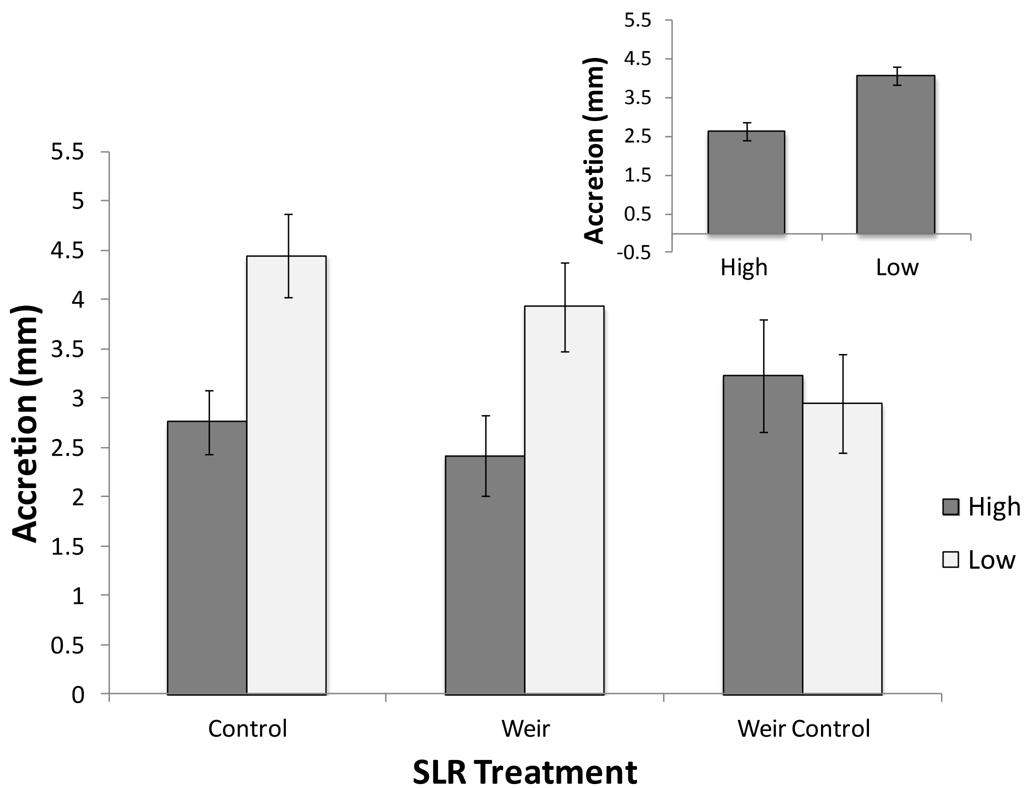

Figure 4. Average surface accretion (mm ± 1 SE) from August to December 2013 across all three experimental clusters at low and high relative elevations within control, weir, and weir control plots, regardless of initial planting density. *Inset*: Average surface accretion (mm ± 1 SE) from August to December 2013 across all three experimental clusters at low and high relative elevations, regardless of SLR treatment or initial planting density.

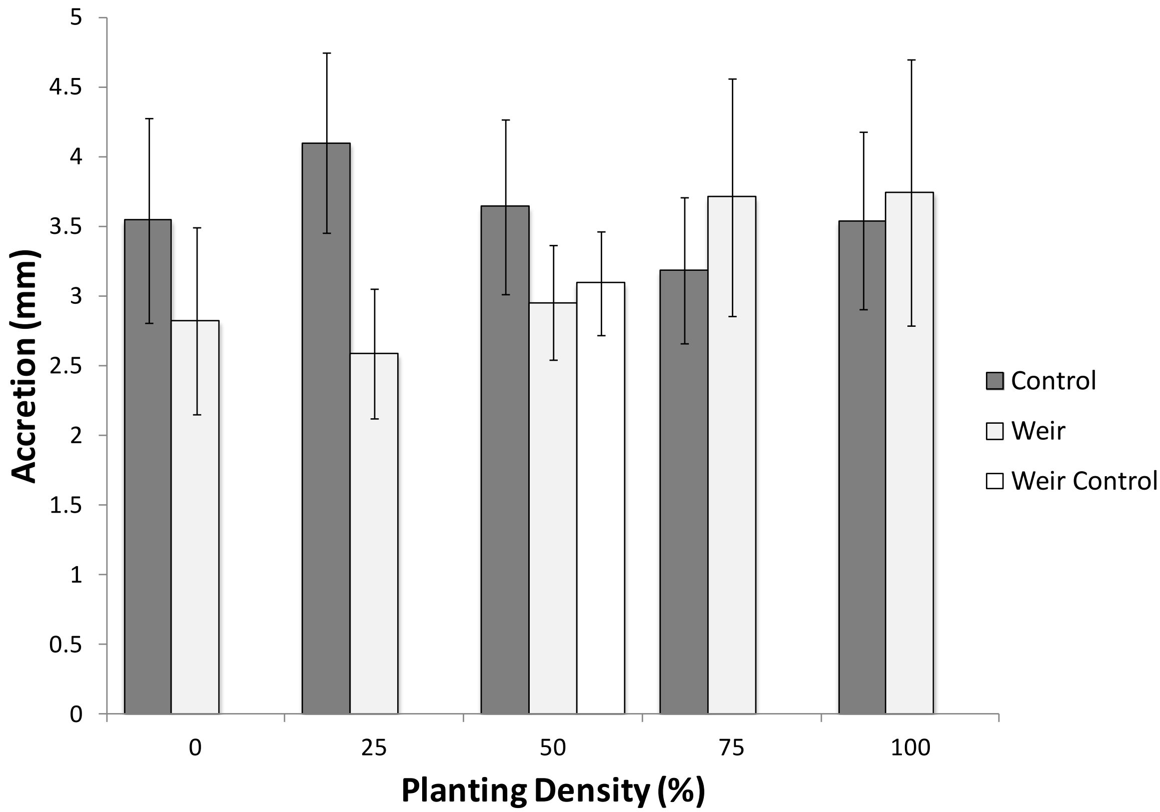

Figure 5. Average surface accretion (mm ± 1 SE) from August to December 2013 across all three experimental clusters for the five initial planting densities within control, weir, and weir control plots, regardless of relative elevation.

A.4.2. Plant diversity

Plant diversity was measured after the first growing season within each plot. Initially, the plant community within the created marshes consisted of one species, *Juncus roemerianus*. After the first growing season, however, an additional 13 species had been identified. Plant species richness tended to increase with increasing planting density, and tended to be slightly higher in weir plots (SLR of 2030) than in controls, particularly at low (0%) and intermediate (50, 75%) planting densities (Figure 6).

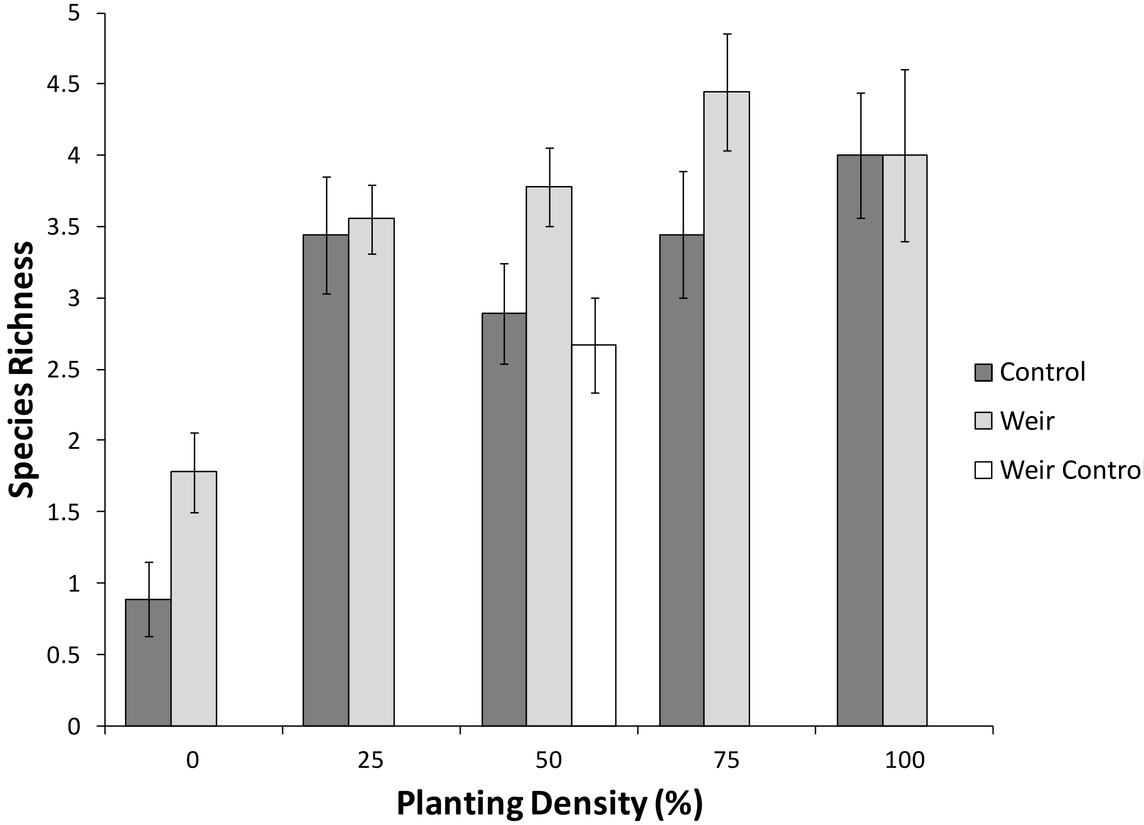

Figure 6. Average species richness (no. ± 1 SE) after one growing season across all three experimental clusters for the five initial planting densities within control, weir, and weir control plots.

A.5. Weir methodology experiment

From June 28- July 26, data was collected to demonstrate the weirs can mimic varying degrees of SLR. Weirs in each cluster were set to mimic different degrees of SLR (years 2030, 2040, 2050) by altering the drain valve height. The results show the weirs were successful at mimicking varying degrees of SLR while still retaining natural tidal oscillations. A methodology publication will be submitted in the future to inform other researchers of an in-situ alternative to current methods to mimic SLR. Also this work has been presented at several scientific conferences already and will continue to be presented. Below you will find a summary for each SLR scenario (2030, 2040, and 2050) mimicked. For the figures, weir 1 and weir 2 are areas inside of weirs, controls are areas of the marsh with no weir present (ambient SLR), and weir control is a weir with no face to allow natural tidal movement.

For the 2030 scenario, weirs resulted in a 10.8 cm (16.4%) increase in inundation relative to controls at low tide during the 4 week study period, or a 1.7 cm (2.6%) increase in inundation relative to controls (Figure 7).

For the 2040 scenario, weirs resulted in a 12.6 cm (22.2%) increase in inundation relative to controls at low tide during the 4 week study period, or an overall 3.1 cm (5.5%) increase in inundation relative to controls (Figure 8).

For the 2050 SLR scenario, weirs resulted in a 15.7 cm (27.0%) increase in inundation relative to controls at low tide during the 4 week study period, or an overall 4.5 cm (7.8%) increase in inundation relative to controls. Weir controls resulted in a 2.3 cm (4.0%) increase in inundation relative to controls at low tide, or an overall 0.6 cm (1.0%) increase in inundation relative to controls (Figure 9).

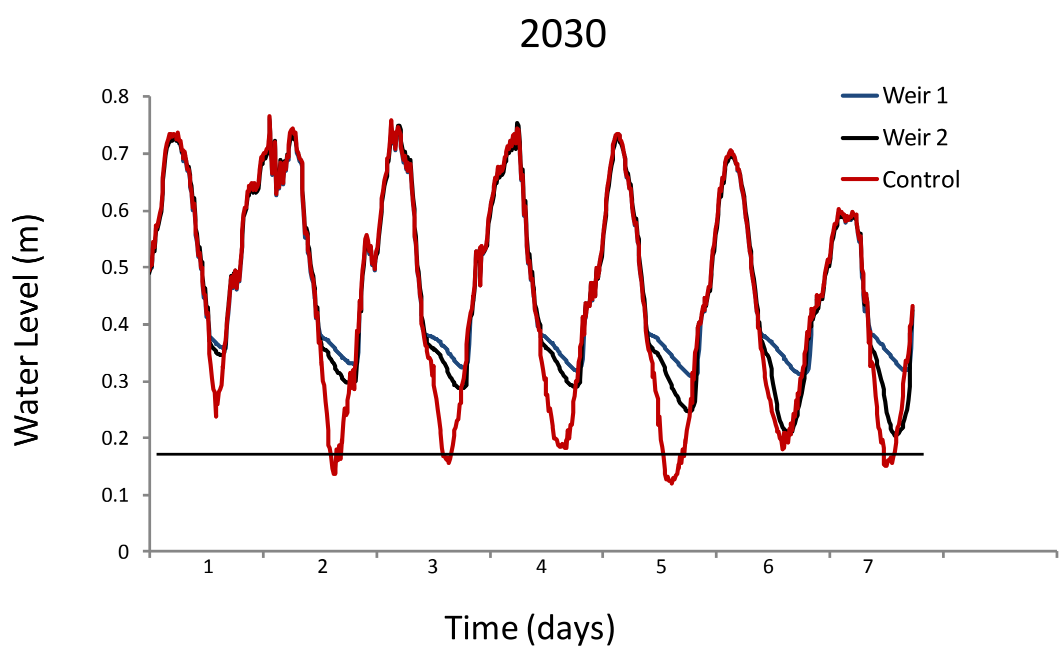

Figure 7. Change in water level during 1 week of a 4 week study period in controls compared to weirs simulating a 2030 sea-level rise scenario. The horizontal line marks the soil surface.

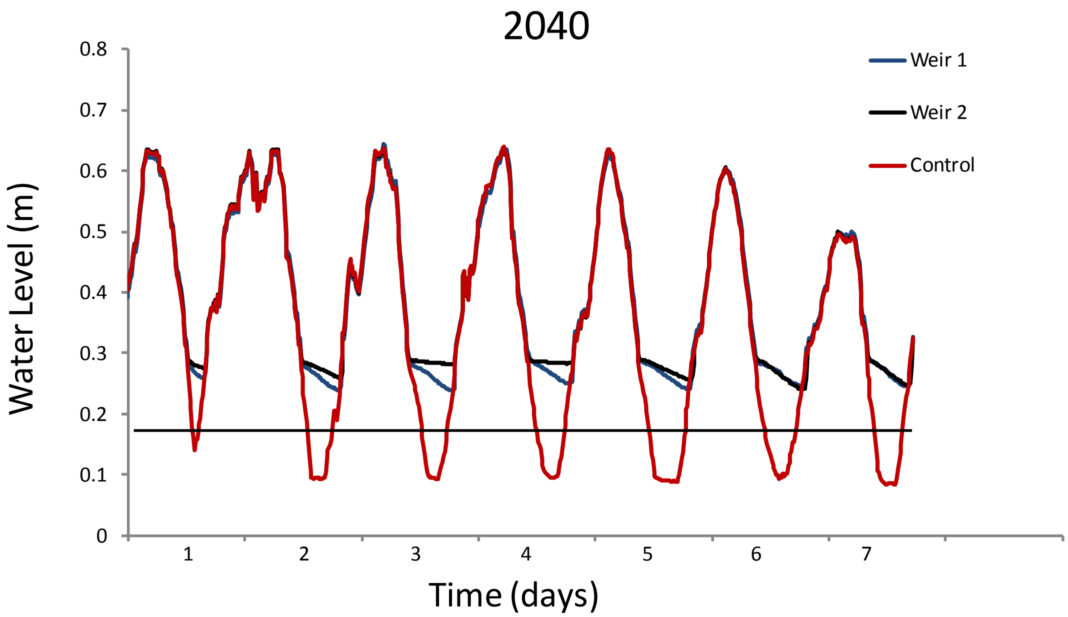

Figure 8. Change in water level during 1 week of a 4 week study period in controls compared to weirs simulating a 2040 sea-level rise scenario. The horizontal line marks the soil surface.

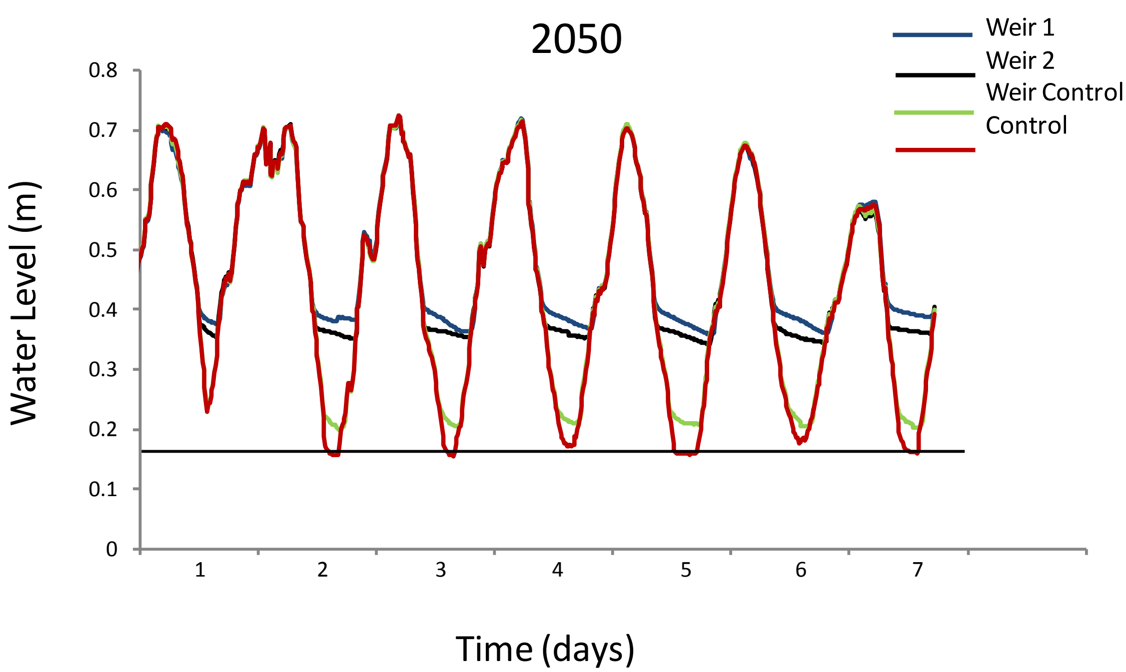

Figure 9. Change in water level during 1 week of a 4 week study period in controls compared to weirs simulating a 2050 sea-level rise scenario. The horizontal line marks the soil surface.

B. Working with Intended Users:

The integration of input from intended users of this research has been integral throughout the entire process of this project. As mentioned in the previous section and reports, we hold regular MAT meetings after experiments to discuss the results and modify the approach (if necessary) for the next round of experiments. This type of interaction with actual end users (MAT team) guarantees this research will be used by the intended users. At the most recent MAT meeting, the MAT suggested a comparison of the low flow nutrient loading scenario across 2 restoration sites. Previously, we have only run one loading scenario in a given site, but a comparison of the same flow scenarios across 2 sites will increase our sample size, thereby increasing the strength of our conclusions.

C. Progress on project objectives for this reporting period:

All objectives for this reporting period were achieved or are currently in progress and these objectives were: 1) See the Progress Overview section (A) for a more detailed description of the completion of project objectives timeline. In the next 6 months, we have 3 project objectives: 1) repeat the Conservation and Restoration Awareness Survey to increase the sample size of responses, 2) conduct another nutrient experiment, and 3) meet with the MAT to present the survey and nutrient enrichment experimental results as well as finalize the decision support tool. A tentative schedule for these goals are to repeat the survey throughout the summer, run the next nutrient experiment in Spring/Summer and have the MAT meeting in late summer.

D. Benefits to NERRS and NOAA:

A direct benefit to NERRS, NOAA and the general public, for this reporting period, is the continued growth of approximately 75 square meters of restored marshland that was previously the steep bank of a dredged canal. This marshland has attracted birds, crabs, fish and fishermen already. This marsh is also filtering some of the nutrients from groundwater and runoff pollution, thereby reducing excess nutrient loading into the canals they are planted along. The results from the Conservation and Restoration Awareness Survey will provide insight to NERRS and NOAA about the perceptions of conservation and restoration by the general public. Several presentations at international science conferences about this work also directly benefits NOAA and the NERRS since these presentations increase the reach of this project to scientist and decision makers worldwide.